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DRAWINGS ATTACHED

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(54) IMPROVEMENTS IN SELECTIVE DETECTION OF IONS

(71) We, GENERAL ELECTRIC COMPANY, a corporation organized and existing under the laws of the State of New York, United States of America, residing at 1 River Road, Schenectady 12305, State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

The present invention relates to an ion detector; more especially, it relates to a detector capable of selectively detecting ions of a narrow range of mobilities in a gas such as air and giving an indication or measurement of their relative abundance and is especially adapted for the measurement of the small ions of atmospheric physics.

In the examination of the ion content of a gas such as air, for example in air pollution studies, it is frequently desired to determine the relative abundance of ions having a relatively narrow range of mobilities, which may be related to their size or composition. In this respect, mobility of these ions may be defined as the velocity of an ion in centimeters per second in a unit field.

The previously available detectors have not been capable of as sharp discrimination as desired.

The present invention provides an apparatus for measuring the abundance in a gas of ions having mobilities substantially equal to a preselected value comprising

a conduit;
 means for passing a stream of an ion containing gas through said conduit at a constant known velocity;

means for selectively blocking the flow of ions in said conduit without impeding the flow of said gas stream;

means for maintaining ions having

mobilities substantially equal to said preselected value substantially stationary in said gas stream when said ion blocking means is operative;

means for removing ions having mobilities different from said preselected value from the gas stream in the zone wherein said selected stationary ions are located, said means for removing ions being cooperable with said ion maintaining means and said ion blocking means or forming part thereof; and

means for collecting said selected ions and determining their abundance.

In the apparatus of the invention said means for selectively blocking the flow of ions may include a pair of gas-permeable electrically activated gates in said conduit and longitudinally spaced apart at upstream and downstream locations with respect to the direction of the flow of said gas stream to define a chamber therebetween, said gates being selectively connectable to a reference potential to permit free passage of gas and ions therethrough, and alternatively to a source of direct current potential to permit free passage of gas but to prevent passage of ions therethrough; in this form of construction each of said gates may comprise three spaced gas-permeable electrodes, the outer two of which are connected to said reference potential and the intermediate electrode being selectively connectable to said reference potential and alternatively to said source of direct current potential. Said means for maintaining ions having said preselected mobilities substantially stationary in said gas stream may comprise a gas-permeable electrode in said chamber close to said downstream gate. Said means for removing ions may include the reference potential electrode of each gate defining said chamber. Said means for collecting said selected ions may include a first gas-permeable electrode connected to said refer-

ence potential in said conduit downstream of said downstream gate, said first gas-permeable electrode being provided with means for measuring electrical current, and
5 a second gas-permeable electrode adjacent to and downstream of said first gas-permeable electrode; in this form of construction there may be provided electrical circuit means for applying electrical potentials of the same size to said intermediate
10 electrode of each said gate and to said gas-permeable electrode in said chamber close to said downstream gate.

In one embodiment of the apparatus of
15 the invention, a gas containing ions of a wide range of mobilities may be passed through a conduit which includes a pair of spaced gates each comprising two ion collector gas-permeable electrodes, a further
20 gas-permeable electrode located between said gates but close to the gate which is downstream when a gas stream is passed through the conduit, a gas-permeable ion collector electrode associated with a current
25 measuring means located adjacent to and downstream of the downstream gate, and a gas-permeable retarding electrode located adjacent to and downstream of the ion collector electrode associated with said current
30 measuring means (i.e. the current measuring electrode). It will be understood that the designation "gas-permeable" indicates various elements and members which do not restrict the flow of the gas through the conduit which contains them. For convenience,
35 hereinafter the pair of gates comprising two ion collector gas-permeable electrodes will be referred to as the "upstream gate" and the "downstream gate", with respect to the direction of gas flow; thus each of the
40 gates comprises an upstream electrode and a downstream electrode.

In making a measurement with the embodiment described in the preceding paragraph, both gates are closed, in that while
45 the air flow continues at a constant rate at which the gas stream is passed through the conduit, no new ions are admitted to the space in the conduit between the gates. Simultaneously, an electric field of a pre-determined strength is applied between the
50 electrode close to the downstream gate but upstream thereof and the downstream electrode of the upstream gate such that the first mentioned electrode is at a positive
55 potential and the second mentioned electrode (i.e. gate electrode) is grounded. All of the negatively charged ions in the gas between the gates will be accelerated downstream and be collected by the positive
60 electrode. The field between the positive potential electrode and the grounded electrode of the upstream gate will exert a retarding force on the positively charged
65 ions which will result in those ions having

the higher mobilities being driven upstream where they are collected by the grounded electrode of the upstream gate. Those ions having the lower mobilities are carried by the gas flow downstream against the retarding field to pass through the gas-permeable positive potential electrode and are collected by the downstream gate. Those ions having a positive charge and the desired intermediate mobility range will be held in the space
70 between the gates in a more-or-less metastable condition. In other words, depending upon the gas velocity and the distance between the gates, ions having mobilities extending over a range of mobilities above
80 and below a single desired mobility value which is determined by the gas flow rate and the particular field strength will be trapped between the electrodes. Those having higher mobilities than the previously
85 mentioned single mobility and located farther downstream from the upstream gate will take longer to move upstream to be collected than those of the same mobility located nearer the upstream gate. Those
90 ions having lower mobilities than the single desired mobility will be carried by the gas stream against the field toward the downstream gate to be collected at a rate which will depend upon their individual mobilities,
95 and the time required to remove ions of either higher or lower mobilities from the space between the gates will depend upon the degree of the difference of the ion's mobilities from the single desired mobility
100 and the distance of the ion from its respective collector. After a period of time has elapsed, the only ions remaining between the gates are ions having a narrow band of mobilities extending above and below the
105 single desired mobility. The longer the time period, the narrower this band of mobilities becomes. After sufficient time has elapsed, the field is removed, the downstream gate is opened and a positive potential is applied to the electrode downstream
110 of the current measuring electrode which is of sufficient magnitude to prevent any positive ions from being carried through the current measuring electrode. All the remaining ions are swept by the gas flow through
115 the downstream gate where they are collected by the current measuring electrode and discharged thereby. The substantially simultaneous collection and discharge of ions of selected mobility results in a pulse
120 of current delivered to the current measuring apparatus over a short period of time, the magnitude of which is related to the abundance of positively charged ions having a narrow range of mobilities about the
125 single desired mobility.

The more detailed description of the invention which follows will be better understood when read in conjunction with the
130

accompanying drawings in which

Fig. 1 is a schematic illustration of a preferred embodiment of the invention;

Fig. 2 is a graphical representation of the distribution of the abundance of ions having mobilities up to a mobility of about 2; and

Fig. 3 is a graphical representation of the nature of the current pulse produced when the ions of selected mobilities are collected and discharged.

More specifically, Fig. 2 illustrates a typical distribution of the abundance of ions in a gas such as air versus their relative mobilities. The sharply rising portion of the curve at lower mobilities represents particles approaching dust particles in size, while the right hand portion of the curve from the point showing a mobility greater than about 0.2 represents the small-ion mobility range for which this invention is especially useful. The vertical dashed lines illustrate a useful range in mobilities about a single selected mobility of 0.5 for such ions which the apparatus of this invention may be employed to detect and measure, it being understood that this particular selected mobility and the width of the range as shown are merely exemplary and are not to be considered as limiting in any manner.

One preferred embodiment of the invention is schematically illustrated in Fig. 1, wherein an elongated conduit 1 of a material having a relatively high electrical resistivity and having a uniform cross-sectional area and configuration, which is preferably circular, which provides means through which a constant flow of a gas to be measured may be passed, as shown by the arrows at the ends of the conduit, in a left to right direction. An upstream gate 10 is supported in the conduit as shown and is comprised of a pair of parallel grounded electrodes 11 and 12 which are supported in spaced parallel relationship on either side of an intermediate electrode 13, which is connectable to an external circuit by lead 14. A similar gate 20 is provided downstream of gate 10 and includes grounded electrodes 21 and 22 and intermediate electrode 23 is provided with a lead 24.

A high potential electrode 25 (which may be grounded) is supported by the conduit close to and upstream of gate 20, and is connectable to an external circuit by lead 26 to which lead 24 connects.

Lead 14 is connected to a two position switch 30 and lead 26 is connected to a two position switch 31 as shown, whereby leads 14 and 26 may be selectively a) connected to each other through switch 31 and alternatively to a dc power supply 32 or to ground by switch 30, or b) leads 24 and 26 may be grounded by means of switch 31 while lead 14 is connected to the power supply 32

through switch 30. It should be noted that switch 31 and its function may be eliminated if desired.

Downstream of gate 20 and in spaced parallel relationship thereto is a collecting and current measuring electrode 35 which is provided with a lead 36 to an externally located conventional current measuring apparatus A through which current may pass from electrode 35 to ground, as shown.

A positive potential electrode 40 is supported in the conduit in spaced parallel relationship to and downstream of electrode 35. Electrode 40 is connected to a source 80 of dc potential.

It will be understood that all the electrodes described are gas-permeable electrically conductive membranes having substantially the same area and configuration as the interior of the conduit 10 and preferably are comprised of fine mesh metal screening but which do not appreciably reduce the rate of air flow through the conduit and in fact contribute to maintaining uniform gas velocity across the conduit.

A conventional voltage divider 50 is provided which comprises a plurality of spaced circumferential conductive plates interconnected by resistors 52 and terminally connected to lead 26 and to grounded electrode 12, as shown, to provide a relatively uniform field gradient between upstream gate 10 and the electrode 25 which can be at a high potential.

As an example of a typical measurement utilizing the present invention, assume that it is desired to measure ions having a mobility of about 0.5 centimeter per second per volt per centimeter in air flowing through conduit 10 at 25 centimeters per second and that the distance between grounded electrode 12 of gate 10 and the potential electrode 25 is 12.5 centimeters. Under these conditions, ions in the air stream will pass from electrode 12 to electrode 25 in 0.5 second when all the electrodes are at ground potential. Continuity between leads 14 and 26 is established by closing switch 31 and switch 30 connects these leads to dc power supply 32 and a positive potential is applied to electrodes 13, 25 and 23, while electrodes 11, 12, 21 and 22 remain at ground potential. At this time, no additional ions may pass into conduit 1 through gate 10 since a large field gradient is present between electrodes 11 and 13 such that all incoming positively charged ions will be collected by electrode 11 and all incoming negatively charged ions will be collected by electrode 13. If a positive potential of 625 volts is applied to electrode 25, there will be a field of 50 volts per centimeter in the region between electrodes 12 and 25. In such a field in still air a positively charged

ion with a mobility of 0.5 centimeter per second per volt per centimeter would move toward electrode 12 with a velocity of 25 centimeters per second. This, however, is the velocity, in the opposite direction, of the air stream so that such an ion would tend to remain stationary in the space between electrodes 12 and 25. Assume that the sample contained between the upstream gate 10 and the electrode 25 initially contained both positive and negative ions of a broad band of mobilities. For simplicity, assume the small diameter circles at the left of the chamber in Fig. 1 represent ions having higher mobility than 0.5, that the intermediate size circles represent ions with a mobility of 0.5, and the large diameter circles represent ions having a mobility less than 0.5. The positive ions of higher mobility will be moved upstream by the field and collected by electrode 12, the positive ions having a mobility of 0.5 will be held in place and the positive ions having mobilities less than 0.5 will be carried by the air stream against the field through electrode 25 and collected by electrode 21 of gate 20. All negative ions will move to electrode 25 and be collected at that point. After an appropriate time interval, the potential is removed from electrodes 25 and 23 permitting the remaining ions which have mobilities in a band about 0.5 to be carried through electrode 25 and gate 20 by the air stream and collected and discharged by electrode 35 producing a current pulse such as shown in Fig. 3 which is detected and measured by the current measuring apparatus A. A positive potential which may be of the order of about 150 volts is applied to electrode 40 to prevent any positive ions from being carried through electrode 35. During the measuring portion of the operation when electrodes 25, 21, 22 and 23 are at ground potential, upstream gate 10 may be kept closed by leaving switch 30 connected to positive potential source 32 while connecting lead 26 to ground through switch 31. However, ideally the incoming gas has a uniform velocity across the conduit, i.e. when gate 10 is opened the incoming ions will advance as a plane front. If, in a cyclic operation of the apparatus, the gates are opened and closed before the ions in the new sample can reach the current collecting electrode and preferably before they reach the potential electrode 25, switch 31 may be eliminated.

If, under the conditions previously assumed, the gates are open for nearly 0.5 second and then closed, the space between electrodes 12 and 25 is nearly filled with the ion-bearing new air sample, but none reach the potential electrode 25 or the current collecting electrode 35. If the gates are energized and electrode 25 is at a positive

potential of 625 volts for one second, positive ions of a mobility of 0.75 or greater will be forced against the air flow to upstream gate 10 regardless of their location in the conduit between electrodes 12 and 25 when the voltage was applied. Positive ions with a mobility of less than 0.5 will move toward electrode 25 at somewhat less than the air velocity. For example, an ion of 0.25 mobility will move toward electrode 25 with a velocity of $25 - 12.5 = 12.5$ centimeters per second and if the potentials are applied for one second, all positive ions of this mobility or less will be removed from the zone between electrodes 12 and 25. Thus, only positive ions with mobilities between 0.25 and 0.75 will remain between the gates after one second. Obviously, if the potentials are maintained for longer periods of time, the width of the band of mobilities will be decreased.

While the foregoing disclosure and specific example has been directed to the measurement of positive ions, it will be apparent that negative ions may be similarly measured by merely reversing the sign of the applied potentials.

It will be apparent to those skilled in the art that any convention gas pumping means, preferably located downstream of electrode 40 may be employed provided it is capable of producing a constant, controllable gas velocity through the conduit 1. Since such pumps are commercially available, no particular pump means has been illustrated.

Furthermore, while certain of the electrodes have been disclosed as connectable or connected to ground, it will be apparent to those skilled in the art that a relatively low reference potential may be used instead of ground potential.

WHAT WE CLAIM IS:—

1. An apparatus for measuring the abundance in a gas of ions having mobilities substantially equal to a preselected value comprising

a conduit;

means for passing a stream of an ion containing gas through said conduit at a constant known velocity;

means for selectively blocking the flow of ions in said conduit without impeding the flow of said gas stream;

means for maintaining ions having mobilities substantially equal to said preselected value substantially stationary in said gas stream when said ion blocking means is operative;

means for removing ions having mobilities different from said preselected value from the gas stream in the zone wherein said selected stationary ions are located, said said selected stationary ions are located, said means for removing ions being cooperable

with said ion maintaining means and said ion blocking means or forming part thereof; and

means for collecting said selected ions and determining their abundance.

2. An apparatus according to Claim 1, wherein said means for selectively blocking the flow of ions includes a pair of gas-permeable electrically activated gates in said conduit and longitudinally spaced apart at upstream and downstream locations with respect to the direction of the flow of said gas stream to define a chamber therebetween, said gates being selectively connectable to a reference potential to permit free passage of gas and ions therethrough, and alternatively to a source of direct current potential to permit free passage of gas but to prevent passage of ions therethrough.

3. An apparatus according to Claim 2, wherein each of said gates comprises three spaced gas-permeable electrodes, the outer two of which are connected to said reference potential and the intermediate electrode being selectively connectable to said reference potential and alternatively to said source of direct current potential.

4. An apparatus according to Claim 2 or 3, wherein said means for maintaining ions having said preselected mobilities substantially stationary in said gas stream comprises a gas-permeable electrode in said chamber close to said downstream gate.

5. An apparatus according to any one of Claims 2 to 4, wherein said means for removing ions includes the reference potential electrode of each gate defining said chamber.

6. An apparatus according to any one of Claims 2 to 5, wherein said means for collecting said selected ions includes a first gas-

permeable electrode connected to said reference potential in said conduit downstream of said downstream gate, said first gas-permeable electrode being provided with means for measuring electrical current, and a second gas-permeable electrode adjacent to and downstream of said first gas-permeable electrode.

7. An apparatus according to any one of Claims 4 to 6, in which there is provided electrical circuit means for applying electrical potentials of the same size to said intermediate electrode of each said gate and to said gas-permeable electrode in said chamber close to said downstream gate.

8. An apparatus according to Claim 1, constituted by a pair of spaced gates each comprising two ion collector gas-permeable electrodes, a further gas-permeable electrode located between said gates but close to the gate which is downstream when a gas stream is passed through the conduit, a gas-permeable ion collector electrode associated with a current measuring means located adjacent to and downstream of said downstream gate, and a gas-permeable retarding electrode located adjacent to and downstream of said ion collector electrode associated with said current measuring means.

9. An apparatus for measuring the abundance in a gas of ions having mobilities substantially equal to a preselected value constructed and arranged substantially as herein described and shown in Figure 1 of the accompanying drawings.

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